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VOLTAGE DEPENDENCE OF BARRIER HEIGHT IN AlN TUNNEL JUNCTIONS*

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(photoemission; room temperature; E)

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We report measurements of barrier heights on Al-AlN-Mg thin-film structures as a function of applied voltage and insulator thickness. These results are in disagreement with currently accepted theories based upon image potential and/or field penetration of the electrodes.

The structures were fabricated by reacting a freshly evaporated semitransparent aluminum film in a high-purity N_2 glow discharge at approximately 0.2 torr and subsequently evaporating 0.4-mm square Mg counterelectrodes of several thousand Å thickness. The geometry of the discharge was arranged so as to create a gradient in the AlN thickness over the 1-in. length of the sample. Thus samples between 35- and 90-Å thickness were available on a single substrate. Thicknesses were determined from the sample capacitance assuming a dielectric constant of 8.5. The capacitance increased by only about 1% with dc bias up to 10^6V/cm in either direction. Photoresponse was measured with the beam from the monochromator incident on the Al electrode through the glass substrate. Values of the barrier height were determined from plots of the square root of the photoresponse vs photon energy, as previously reported.[1,2] With no dc bias applied to the sample a net photocurrent was observed corresponding to emission of electrons from the Al electrode.

The dependence of the zero bias barrier height on insulator thickness is shown in Fig. 1. Except for a small decrease in barrier height due to image force effects at thicknesses much lower than those used here, no dependence of this magnitude is expected on the basis of present theoretical models.

By applying positive bias to the Mg electrode, photoemission from the Al could be enhanced and the barrier height could be measured as a function of applied dc voltage. With negative bias applied to the Mg, the form of the superposed photocurrents was such that accurate determinations of the barrier heights was possible only over a very limited range of experimental conditions. The results of the Mg positive measurements are shown in Fig. 2. On the basis of an image force model, only a very weak dependence on voltage is expected. It appears that with thinner samples at higher biases, the expected behavior is approached. However over most of the range of experimental conditions, large deviations are apparent. It should be noted that although the I-V characteristics of the samples over the entire range were similar to others widely reported in the literature, only in very thin samples (<50 Å) was accurate quantitative agreement with tunneling theory obtainable. In this case the dependence upon thickness, voltage, and temperature were all consis-

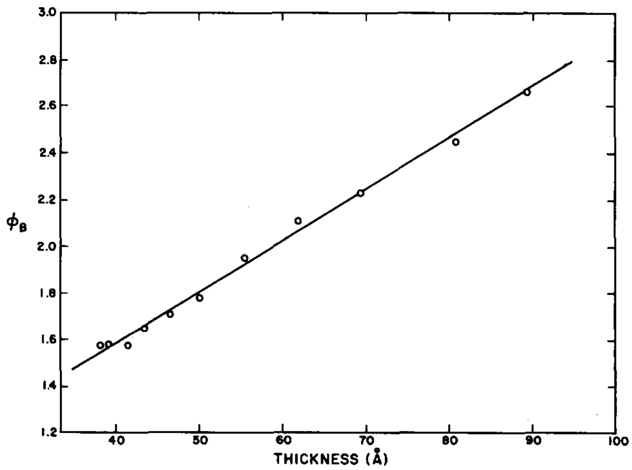

Fig. 1. Variation of zero bias barrier height (in eV) of Al-AlN-Mg structures with AlN thickness.

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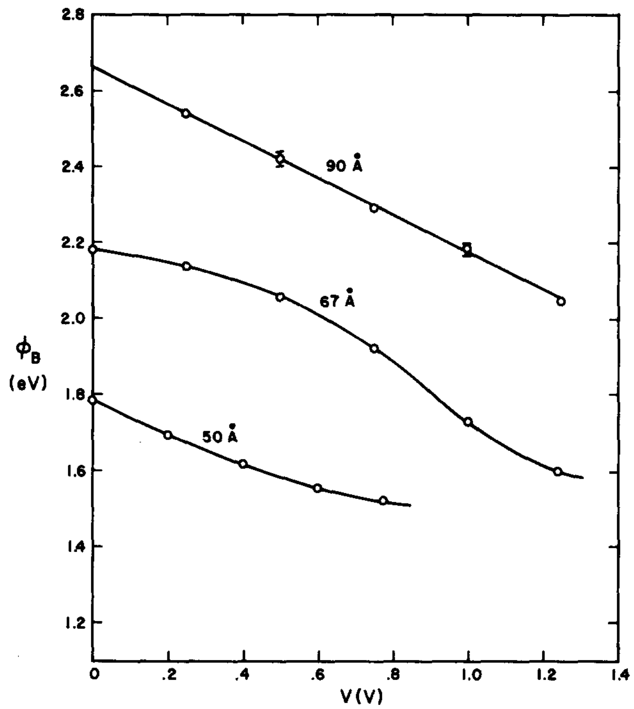

Fig. 2. Variation of barrier height with applied bias (Mg^+) for several AlN thicknesses.

tent with the classical tunneling formulation indicating barriers of approx. 1.7 eV. However, for slightly thicker samples, deviations in the I-V characteristic and in the temperature dependence were apparent in just the range where the variations in barrier height become pronounced. These anomalies persisted even to 4.2°K. The origin of these effects is not understood at this time; however it is clear that any serious attempt to fit experimental data with tunneling theory must be accompanied by independent experimental evaluation of all relevant parameters. Although these measurements were made on one specific system, indications are that similar effects exist in Al_2O_3 (ref. 3) and perhaps other materials as well.

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RADIATIVE RECOMBINATION LIFETIMES IN LASER-EXCITED SILICON

(photoconductivity; photoluminescence; radiative decay lifetime < 2×10^{-8} sec; possible method for study of laser pulse shape; E)

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Thermal broadening and the low efficiency of photoluminescence in silicon has prevented the identification of the mechanism of radiative recombination at room temperature. Sinusoidal excitation showed that band-to-band radiative recombination was negligible compared to other supralinear radiative processes.[1]

Additional information concerning these processes was obtained by utilizing very high excitation intensities, correlating the emission with photoconductivity, and by measuring the lifetimes for the decay of radiative recombination.

The data obtained suggest that, at high excitation levels, the dominant donors or acceptors in *n*- and *p*-type silicon respectively act as efficient radiative recombination centers.

Although the starting material (75 to 800 Ω-cm *n*-type, Sb-doped and *p*-type B-doped Si) had lifetimes of the order of 10^{-3} sec as determined by the photoconductive decay methods,[2] photoluminescent experiments with focused xenon flash tubes indicated that the radiative decay lifetimes were less than 10^{-5} sec (a limit imposed by a prolonged tail in the xenon tube output).

Since the self-quenching properties of epitaxially formed GaAs lasers[3] produced well-defined sharp cut-off light pulses having base widths of 2×10^{-8} sec and peak powers of 7.5 W when energized with 50-A, 100-nsec current pulses at room temperature, such a diode was used to excite the silicon.

To permit the direct comparison of photoconductance and photoluminescent decay properties, the Si samples were mounted in an electrolytic cell of the type described in ref. 1.